

Measurement of Transverse SSA for J/ ψ Production in Polarized p+p and p+Au Collisions at PHENIX

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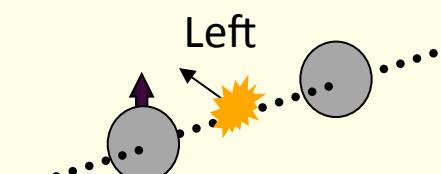


Motivation

Transverse Single Spin Asymmetries A_N

$$A_N = \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}}$$

$d\sigma^{\uparrow(\downarrow)}$ - Cross section for leftward scattering when beam polarization is spin-up(down)



Theory Expectation:

Small asymmetries at high energies

(Kane, Pumplin, Repko, PRL 41, 1689–1692 (1978))

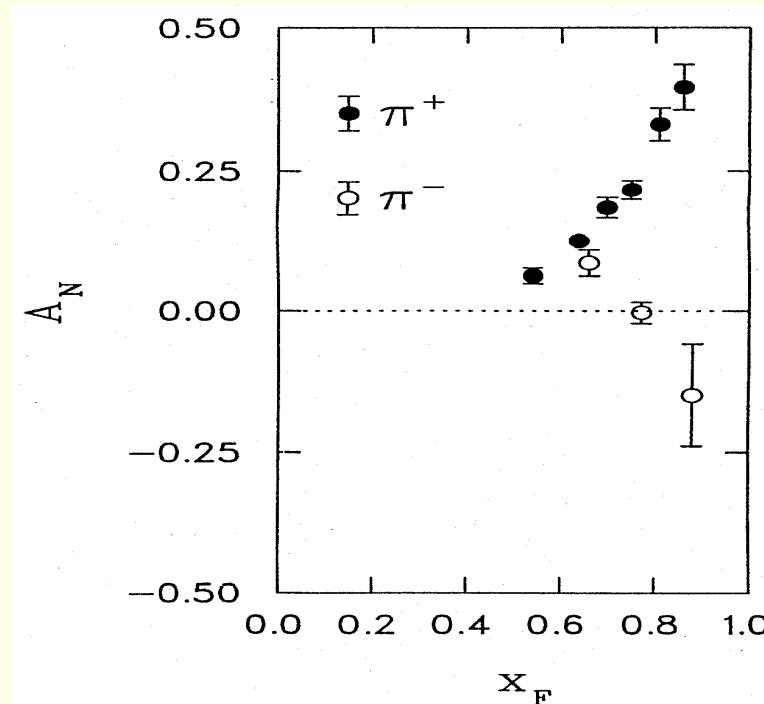
$$A_N \propto \frac{m_q}{\sqrt{s}}$$

$A_N \sim 10^{-4}$ theory

Experiment Observations:

$A_N \sim 10^{-1}$ observed

$$pp^{\uparrow} \rightarrow \pi + X$$



W.H. Dragoset et al., PRL36, 929 (1976)

Theory: Twist-3 Collinear framework

- Multi-parton correlations contribute to the cross section

$$\sigma(Q, \vec{s}) \propto \left| \begin{array}{c} p, \vec{s} \\ k \\ \text{---} \\ \text{---} \\ \text{---} \end{array} \right| + \left| \begin{array}{c} \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \\ t \sim 1/Q \end{array} \right| + \left| \begin{array}{c} \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \end{array} \right| + \dots \right|^2$$

$$A_N \propto \sigma(pT, S_\perp) - \sigma(pT, -S_\perp)$$

$$\propto T^{(3)}(x, x, S_\perp) \otimes \hat{\sigma}_T \otimes D(z) + \delta q(x, S_\perp) \otimes D^{(3)}(z, z) + \dots$$

Twist-3 parton correlation func

Twist-3 parton fragmentation func

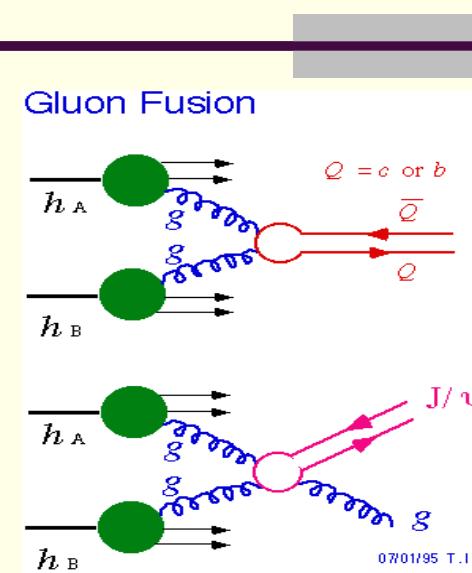
(J.-W. Qiu, G. Sterman,
Single transverse spin asymmetries,
Phys. Rev. Lett. 67, 2264 (1991))

(Z. -B. Kang, F.Yuan, J. Zhou,
Collins Fragmentation and the
Single Transvers spin asymmetry,
Phys. Lett. . B691, 243-248 (2010))

Heavy Flavor A_N

- Heavy flavor production dominated by gluon gluon fusion at RHIC energy
Pythia 6.1 simulation (LO)

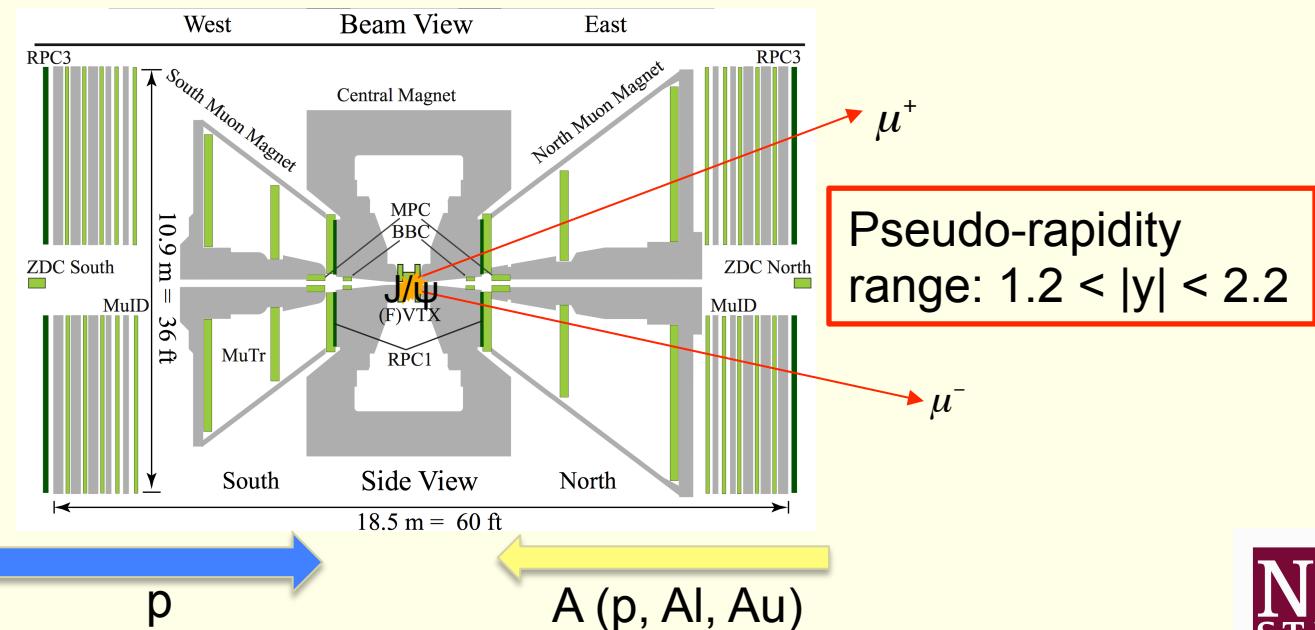
$$\begin{aligned} c\bar{c} : gg \rightarrow c\bar{c} & \quad 95\% \\ b\bar{b} : gg \rightarrow b\bar{b} & \quad 85\% \end{aligned}$$



- Collins mechanism: Correlation between transversely polarized parton and transverse momentum of outgoing hadron.
Heavy Flavor A_N -> minimized Collins effects(gluon has zero transverse spin) -> sensitive to the initial state effects such as a gluon Qiu-Sterman and tri-gluon correlation.
(Z.-B. Kang and J.-W. Qiu, Phys. Rev. D 78, 034005 (2008))
- Also sensitive to J/ψ production mechanisms and QCD dynamics
(D. Sivers, Phys. Rev. D 41, 83 (1990))

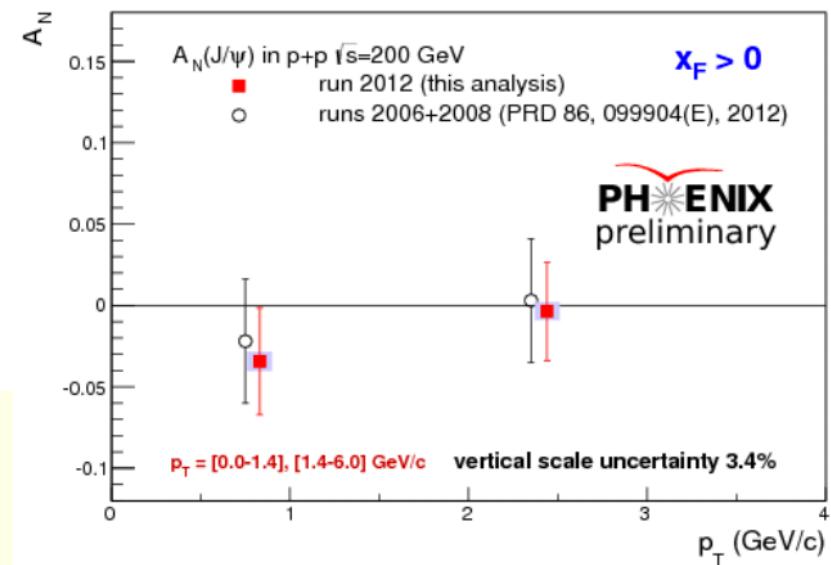
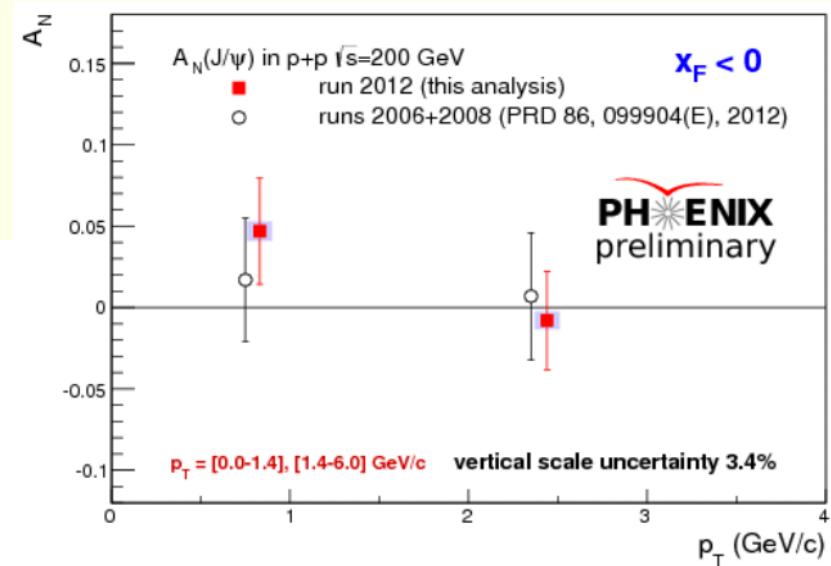
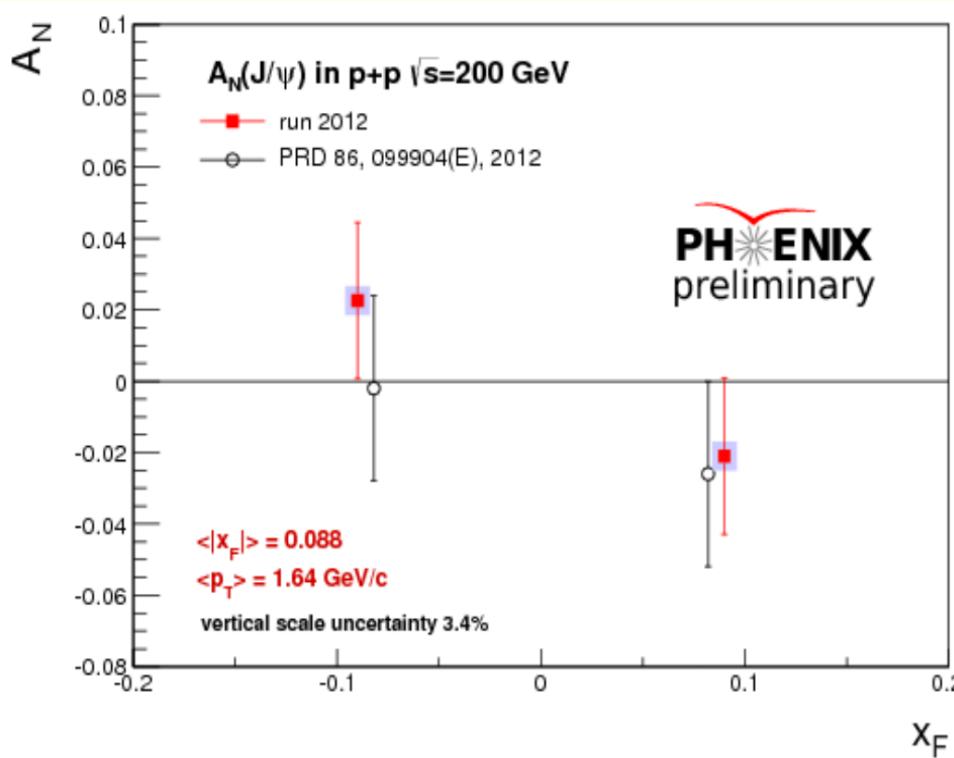
Measurement of Transverse SSA for J/ ψ

- PHENIX measured transversely polarized p+p collision at $\sqrt{s} = 200\text{GeV}$ in 2006, 2008 and 2012.
- $J/\Psi \rightarrow \mu^+ \mu^-$ (dimuon) decay channel is used for J/ψ transverse SSA analysis. Dimuons are measured by the forward arm at PHENIX.



Result and conclusion in previous years

- The result is consistent with 0
- Statistical uncertainties $\sim 2.5\%$



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Why Run15?

- p+p collision at 200GeV in PHENIX

Run	Lumi.\Pol	Luminosity (pb ⁻¹)	Polarization (%)
2006		1.8	53
2008		4.5	45
2012		9.2	60
2015		50	60

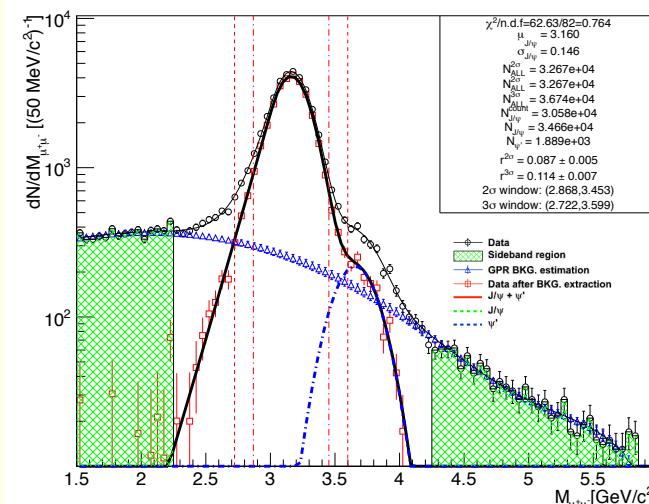
- Approximately 4x more luminosity in 2015 than in all previous runs combined.
- First time PHENIX runs p+Au. Offer a very good chance to test nuclei dependent A_N.

How we measure J/ ψ A_N

■ A_N^{J/psi}:

$$A_N^{J/\psi} = \frac{A_N^{incl} - f \cdot A_N^{BG}}{1-f} \quad \delta A_N^{J/\psi} = \frac{\sqrt{\delta^2 A_N^{Incl.} + f^2 * \delta^2 A_N^{Bkg}}}{1-f} \quad f = \frac{N^{BG}}{N^{incl}}$$

BinningMode_1_Arm0_Charge0_bin0.0_10.0



- Gaussian Process Regression method is used for estimating the background.
- Number of inclusive dimuon events can be got by counting the real data.



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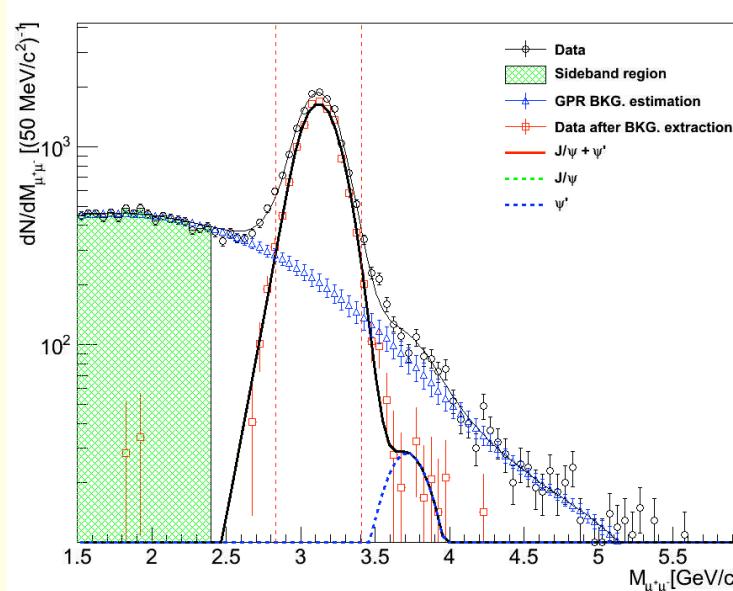


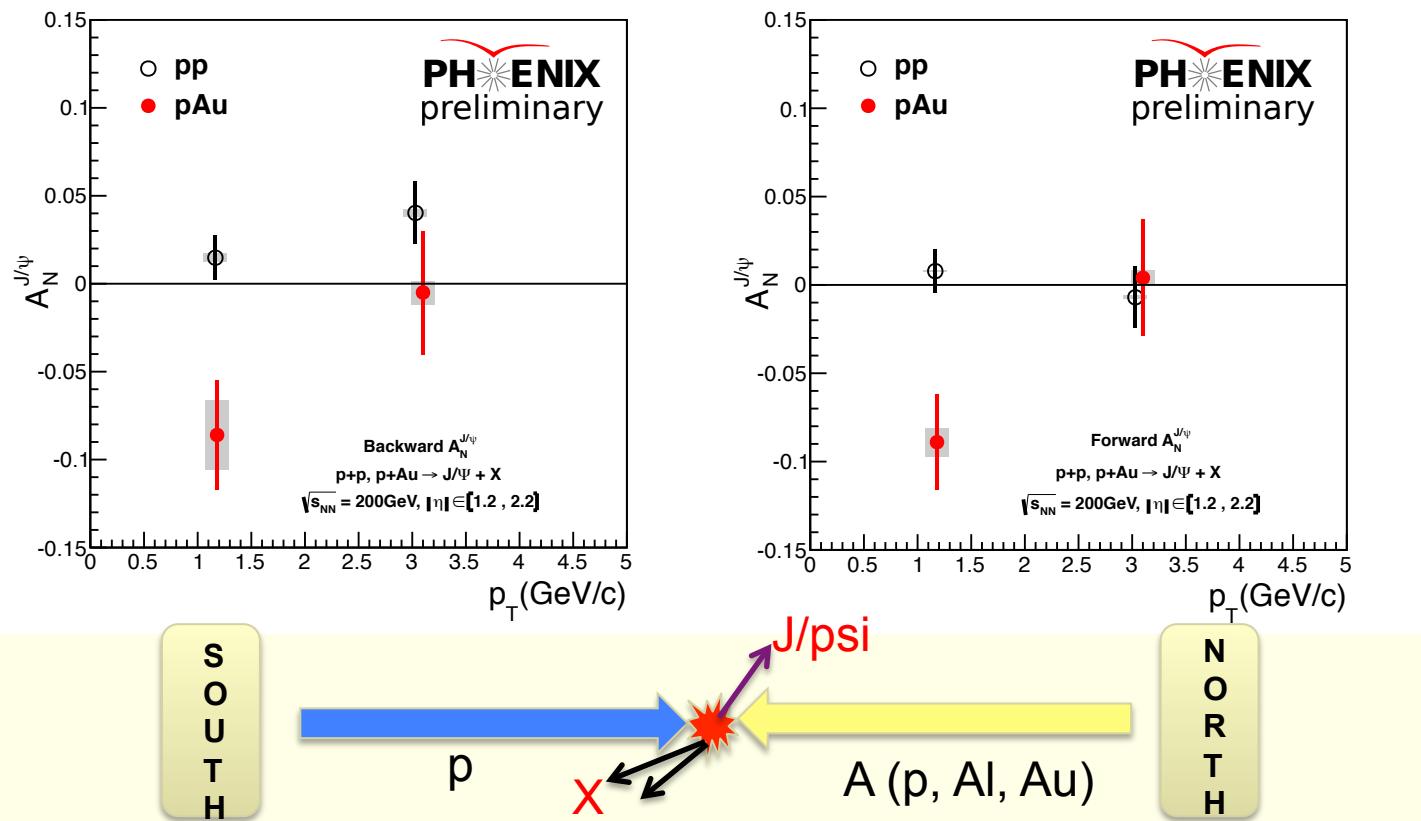
Getting A_N^{Incl} (A_N^{BG})

- A_N^{Incl} and A_N^{BG} are calculated with same method but different mass range of dimuon.

A_N^{Incl} : Unlike sign muon pairs in the invariant mass range $\pm 2\sigma$ around J/ψ mass.

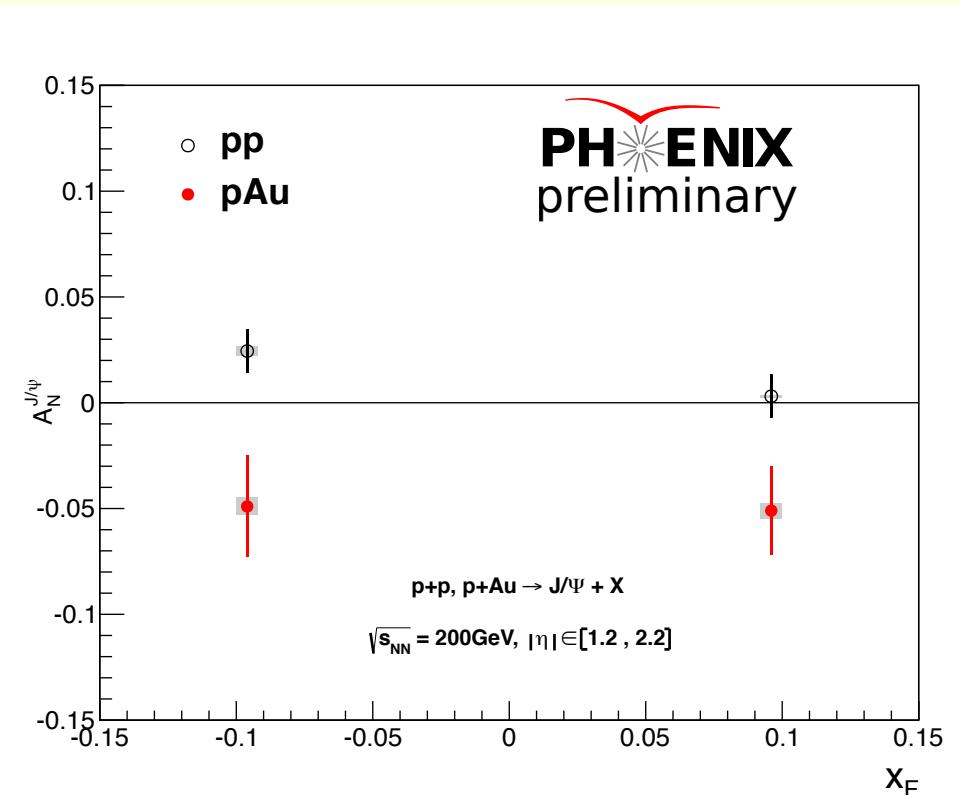
A_N^{BG} : Unlike sign muon pairs in the invariant mass range $1.5 < m < 2.4$



A_N J/psi VS. p_T 

Indication of non-zero A_N (3-sigma level) in first p_T bin with pAu data in both forward and backward direction.
 pp result is consistent with previous result.

A_N J/psi VS. x_F



2-sigma level A_N with pAu data in both forward and backward direction.

pp result is consistent with previous result.



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Summary

- New and very last results for J/psi A_N in pp at 200GeV at PHENIX. Consistent with zero with improved statistical precision ~1%(2015) compare with previous ones ~2%(2006, 2008 and 2012).
- First ever operation with pAu collision. Results for J/psi A_N indicates a negative non-zero asymmetry (3-sigma level) at lower pT. This requires additional experimental and theoretical investigation.
- Further check will be done in next step for pAu result: whether EM process or other processes are involved.



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BACK UP

Theory: TMD framework

■ Transverse Momentum Dependent Functions

If factorization of TMD functions are valid in Semi-Inclusive Deep-Inelastic Scattering (SIDIS) processes, the cross section data are analyzed according to a factorized theoretical expression:

$$d\sigma^{lp \rightarrow lhX} = \sum_q f_{q/p}(x, k_\perp; Q^2) \otimes d\hat{\sigma}^{lq \rightarrow lq} \otimes D_{h/q}(x, p_\perp; Q^2)$$

Parton distribution func

hard-scattering interaction

fragmentation func

TMD Functions
(Sivers, Collins...)

Azimuthal fitting

